Effects of the decoupling of the subsidies on agricultural water productivity

Lorite, I.J. and Arriaza, M.

IFAPA (Junta de Andalucía), Department of Water Management and Agricultural Economics
Centro "Alameda del Obispo", Apartado 3092, 14080 Córdoba, Spain

Abstract— **In this work several performance indicators such as the Annual Relative Irrigation Supply (ARIS) and the Irrigation Water Productivity (IWP), have been considered to evaluate the changes in the cotton irrigation management due to the decoupling of the European Union Subsidies. For this purpose, a modern irrigation scheme, the Genil–Cabra Irrigation Scheme (GCIS) located in Southern Spain, has been selected. The total irrigated area is 6,900 ha with wheat, olive and cotton as the main crops. The irrigation season 2004/05 was the period when the crop pattern and water management trend changed dramatically. From this year to the present the area cultivated with crops with high water requirements like cotton, sugar beet and maize has been reduced almost by half, while the area with low irrigation requirement crops (winter cereals, sunflower or olive) has increased of 37%. After the decoupling of the EU cotton subsidies in 2006, the cotton agricultural practices have changed toward a less intensive production system, including both, lower water application (ARIS for cotton decreased from values higher than 0.8 to 0.5 in the irrigation season 2006/07) and less agrochemical usage. In terms of sustainability, the reform has increased the cotton irrigation efficiency (IWP for cotton increased from around 0.7 €/m3 to 1.0 €/m3 in the irrigation season 2006/07) and has reduced its environmental impact.**

Keywords— **CAP Subsidies, Irrigation, Arable Crops, Spain.**

I. INTRODUCTION

Traditional irrigation management and practices for some crops are changing very quickly in the Spanish irrigation schemes. In this context, traditional crops in which increases of irrigation were advised now are more affected by EU policy than by the weather and the supply restrictions, hence these recommendations must be reconsidered. Due to this, irrigation management research must be focused on the sustainability of the irrigation systems to promote: (a) saving water resources and increasing the water productivity of the irrigation, (b) the optimization of the irrigation allocation and improving the irrigation efficiency.

II. STUDY AREA DESCRIPTION

The study area was the Genil–Cabra Irrigation Scheme (GCIS) located in the province of Cordoba, Spain. The climate in the area is typically Mediterranean with an annual average precipitation of around 600 mm, with a dry summer and an average annual reference evapotranspiration (ETo) of 1,300 mm. The predominant soil types are Chromic Haploxererts (35%) and Typic Xerorthent (35%), according to the Soil Conservation Service (1975) classification.

The GCIS started operating in the 1990/91 irrigation season over a 2,663 ha area that were expanded to some 6,900 ha in 1993/94 [1]. The area has a modern pressurized on-demand delivery system, which provides complete flexibility of frequency, rate and duration of delivery. The method of irrigation has evolved over the years. Until the drought period of 1995/96, almost all the area was watered with hand-move sprinkler systems; gradually, these systems were substituted with permanent sprinkler and drip systems. Since 2001/02, drip irrigation has occupied a greater area than sprinkler irrigation. In recent years, winter cereals, cotton, olive, and maize have been the most frequent crops, occupying over 65% of the area. Other important crops have been sunflower, garlic, sugar beet, beans, peppers, and other horticultural crops.

Significant variations in the crop pattern have been detected in the area. Thus, variation of planted area with winter cereals was affected by the weather conditions. However, in the last years (mainly from

1996) crop pattern has been more stable respect weather conditions but highly affected by the EU policy. Thus, while olive has increased its cultivated area during the whole period, or the area with horticultural crops has been stable, the area cultivated with cotton and sugar beet has been affected by other factors.

The standard water supply availability in the absence of restrictions is about 5,000 m^3 ha-1. In the analysed period (1990/91 to 2006/07), three irrigation seasons had severe irrigation restrictions (1992/93, 1993/94 and 1994/95, with water allocation of 108, 749 and 0 m3 ha-1, respectively). However, since then and until 2004/05 there were not irrigation restrictions in the area, even though two very dry years occurred (1998/99 and 2004/05 with 150 and 223 mm annual rainfall, respectively).

In the last two irrigation seasons (2005/06 and 2006/07) restrictions have been applied in the area and for 2007/08, initially less than 1000 m3/ha will be assigned.

III. DATA COLLECTION

The study was carried out during seventeen irrigation seasons (1990/91 – 2006/07) for which there were annual land use maps provided by the manager of the irrigation scheme. Daily meteorological data to calculate Penman-Monteith reference evapo-transpiration (ETo), and rainfall were obtained from an agrometeorological station located within the irrigation scheme. The irrigation application method was determined by surveying every plot several times throughout the study period. Information about irrigation practices and sowing dates were provided by the irrigation scheme manager or obtained directly from farmers via previous surveys. Crop coefficient curves and crop parameters such as maximum rooting depth were based on Allen et al. [2] and adjusted to local conditions based on advise from the district manager and other local experts.

Cumulative water consumption for each plot was obtained three/four times each irrigation season, allowing to analyse the irrigation management within the irrigation season, except for the drought affected irrigation seasons (1992/93 and 1994/95), when irrigation was substantially limited due to drought. In order to obtain the irrigation requirements for each field, a simulation model based on Allen et al [2] has been developed.

IV. SIMULATION MODEL

To simulate the optimum irrigation requirements and to characterize the current irrigation management for each plot, a soil water balance model was developed. The components of this soil water balance were irrigation, rainfall, run-off, drainage, soil evaporation, and transpiration.

Three soil water contents were defined for each soil layer: the saturated water content, the drained upper limit or field capacity (FC), the lower limit of plant extractable water or wilting point, all determined from soil characteristics. Infiltrated water (precipitation minus run-off) was distributed following a cascade approach along 20 soil layers of equal depth. The amount of water above FC of a given layer was transferred to the layer immediately below. This procedure was repeated for the next layers until drainage from a layer was less than the water deficit below FC of the layer below. Drainage below the soil profile occurs when the soil water content of the deeper layer is above FC. Surface run-off was predicted from daily precipitation using the Soil Conservation Service [3] curve number method. In addition to considering precipitation, soil type, land use and management, the curve number method was modified to include the effect of slope [4].

Crop evapotranspiration (ETc) was calculated from reference evapotranspiration (ETo) and dual crop coefficients for each crop [2]. ETo was calculated with the Penman–Monteith equation. The dual crop coefficient allowed the separation of soil evaporation and maximum crop transpiration. Crop transpiration under water stress conditions was estimated by linearly reducing the maximum crop transpiration from the soil water content at which transpiration starts to be restricted to the soil water content at wilting point [5], both water contents calculated for the whole root zone. The actual crop transpiration was distributed between the different soil layers as a function of root density and water content in each layer [6]. The computed seasonal actual crop evapotranspiration was divided by the seasonal calculated maximum evapotranspiration (ETc) to estimate yield reduction by water deficit using a production function approach [5]. Seasonal crop response factors proposed by them were adjusted according to local experience [7]. We used these crop response factors to determine the slope of the production function from a seasonal crop evapotranspiration deficit of 40% to ETc. In order to account for situations of severe water stress, yield at crop ETc deficit greater than 40% was reduced linearly to zero yield at ETc deficit of 80% [8].

The soil water balance model was used to calculate the depth of irrigation needed to refill the soil profile. These are the net irrigation requirements (NIR). The NIR were divided by an application efficiency accounting for deep percolation losses due to irrigation un-uniformity [9], to obtain the gross irrigation requirements.

V. PERFORMANCE INDICATORS

In order to analyse the evolution of irrigation management in the GCIS in the study period, the Annual Relative Irrigation Supply (ARIS) performance indicator was chosen, defined as:

$$ARIS = \frac{\text{Annual volume of irrigation water inflow}}{\text{Annual volume of crop irrigation demand}}$$

Additionally, an indicator was defined to evaluate the irrigation water productivity in the area. This indicator was named Irrigation Water Productivity (IWP; [10]), and was calculated as follows:

$$IWP\left(€\ m^{-3}\right) = \frac{Inc.\ annual\ value\ of\ agr.\ prod.\ from\ irrig.}{\text{Annual volume of irrigation water inflow}}$$

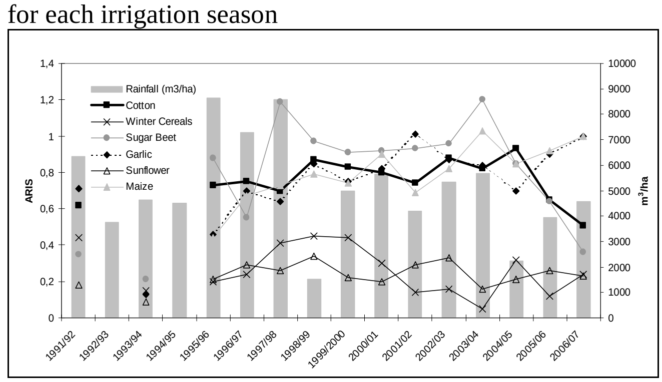
The increase in annual value of agricultural production due to irrigation was calculated as the difference between actual crop yields under irrigation minus rainfed crop yields, times the value of the production in the local markets. To obtain the value of the agricultural production real prices or constant prices using as reference a determined year could be used.

VI. RESULTS AND DISCUSSION

A. Effects of CAP on the irrigation water management

As a result of the decoupling of the EU agricultural subsidies from the successive CAP reforms, it has resulted in a reduction of the input use in the farm management practices [11-12]. In this work, the volume of water applied by the farmers to the cotton has been analysed to detect the change in farmer behaviour due to EU policy differentiating among other possible factors. In Figure 1 could be found values for ARIS calculated by the main crops in the area.

Figure 1. ARIS evolution for the main crops and the rainfall for each irrigation season



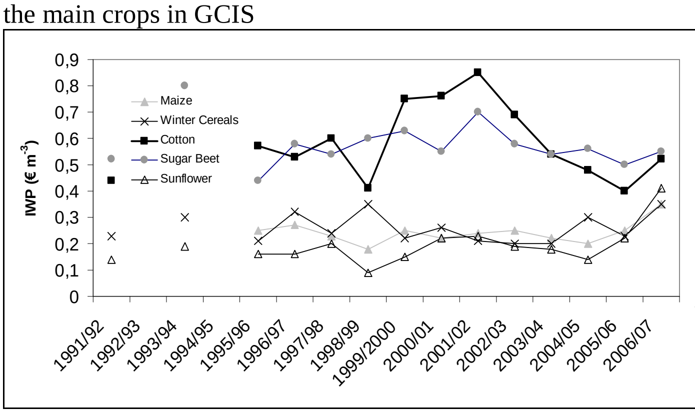
Two clear groups were determined. The first one composed by maize, olive, garlic and wheat, which were not affected by the CAP about water management. In the other group are allocated sugar beet and cotton. ARIS values have suffered slight modifications among years. Thus, some relations have been detected depending on availability of water, weather conditions, *etcetera* [13]. Previous analyses detected that in dry years farmers tried to compensate the scarcity, increasing irrigation applied, relaxing the irrigation schedules when the weather conditions were rainy. In the last two years (2005/06 and 2006/07) rainfall was limited, so an elevated ARIS could be expected, as happened for maize or garlic.

In the past in GCIS, cotton, maize and sugar beet had similar ARIS values (ranged between 0.8 and 1) almost independently of the rainfall or the water availability since, in years with lower water allowance, irrigation of winter cereals or sunflower was transferred to these crops. However with the new EU policy, ARIS values have been reduced in a significant way. Thus, while ARIS for maize was not modified (0.92 for 2005/06 and 1.01 for 2006/07), values for cotton (0.64 and 0.51) and for sugar beet (0.64 and 0.36) significantly decreased (Figure 2). These two crops have been clearly affected by the decoupling of the subsidies (64.2% and 65%, respectively), and the subsequent reduction of the producers' selling price, due to the Mid Term Review of the CAP, making more economically attractive the extensification of their production.

B. Effects of CAP on the irrigation water productivity

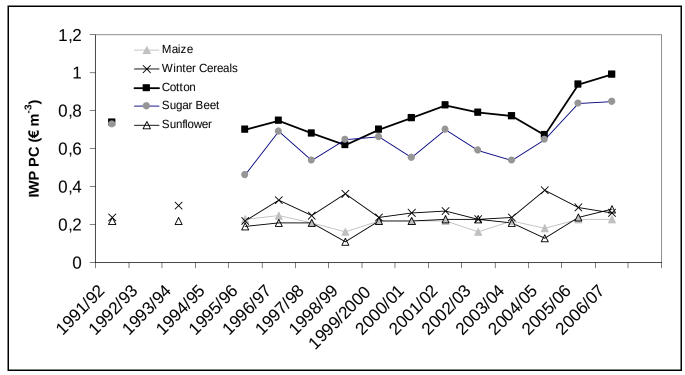
In the study of the water productivity in the Spanish irrigation schemes, traditionally two groups have been defined: cereals and sunflower with very low water productivity (even in some years the irrigation was in the threshold of the profit) and a second group (cotton, garlic, sugar beet or olive) with high values of water productivity. During the 2005-2007 period these differences have been reduced and then in 2006/07 irrigation water productivity for maize was equal to 0.35 vs. 0.52 for cotton (Figure 2) except for crops like garlic or olive which productivity have not been affected by EU policy.

Figure 2. Irrigation Water Productivity (IWP) evolution for the main crops in GCIS



Modifications in the irrigation applied also affected to the irrigation water productivity of the crops: the reduction of yield is lower than the reduction of the water applied hence there is an increase in water efficiency. In order to analyze the water efficiency during the period, constant prices were considered using as reference the prices for the irrigation season 2000/01. In the Figure 3 modified IWP values are shown. Clearly, IWP values showed the increase in the water efficiency at field scale for cotton and sugar beet, while for other crops as maize or wheat the values were constant. Thus, IWP for cotton increased from around 0,7 €/m3 during the previous years to the modification of the PAC policies to 0.99 €/m3 in the last analyzed irrigation season (2006/07), implying an increase of more than 40%. This increase was caused by the deficit irrigation applied to the crop, reducing the losses of the irrigation applied by runoff and deep percolation.

Figure 3. Irrigation Water Productivity (IWP) using as reference the prices in 2000/01 for the main crops in GCIS



VII. CONCLUSIONS

The decoupling of the subsidies due to the Mid-Term Review of the CAP has affected the use of inputs in general and the irrigation applied in particular for sugar beet and cotton. In the last case, the elimination of the intervention price and the subsequent lowering of the producers' selling price have resulted in an extensification of the production with yields 40% lower than the average. From the environmental point of view the reform has increased the cotton irrigation efficiency and it has therefore moved the crop practices toward a more sustainable production system.

Analyzing the irrigation management in the GCIS using two performance indicators as ARIS and IWP could be determined the quantity of the reduction of the inputs to the cotton in Spain. Thus, ARIS was reduced around 40%, from values higher than 0.8 in the previous years to the modifications in the PAC until 0.5 in 2006/07, while the increase of irrigation water productivity was calculated in more than 40% (increase from around 0.7 €/m3 to 1.0 €/m3 in the last year). Both indexes with the crop pattern evolution could be used as valid indicators of the effects of the PAC policies on the Spanish irrigated areas.

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